APPENDIX B: RESIN MODIFIED PAVEMENT (RMP) MIX DESIGN METHOD

B-1. Open-Graded Asphalt Concrete.

a. Preliminary.

(1) Gather representative samples of aggregates and asphalt cement. Sample aggregates according to American Society for Testing and Materials (ASTM) D 75 and asphalt cement according to ASTM D 140. An open-graded asphalt concrete mix design requires a minimum of 45 kg of each aggregate stockpile and 15 L of asphalt cement.

(2) Oven dry aggregate stockpile samples and conducts a sieve analysis (ASTM C 136) on each sample. Determine the combination of aggregate stockpiles that results in a gradation closest to the center of the limiting gradation band specified in CEGS-02548. This stockpile combination will become the blending formula for the open-graded asphalt concrete.

(3) Ensure that the aggregates representing the selected stockpiles and the asphalt cement meet the quality requirements as detailed in CEGS-02548. Measure apparent specific gravity of aggregates (ASTM C 127 and C 128) from each stockpile used in the final gradation. Calculate apparent specific gravity of combined aggregates using the blending formula percentages. Measure specific gravity of asphalt cement (ASTM D 70).

(4) Estimate the optimum asphalt content using the following equation:

$$\text{Optimum asphalt content} = 3.25(")E^{0.2}$$

where

" = 2.65/SG

SG = apparent specific gravity of the combined aggregates

E = conventional specific surface area
 = 0.21G + 5.4S + 7.2 s + 135f

G = percentage of material retained on 4.75-mm sieve

S = percentage of material passing 4.75-mm sieve and retained on 600-µm sieve

s = percentage of material passing 600-μm sieve and retained on 75-μm sieve

f = percentage of material passing 75-μm sieve

(5) Round the calculated optimum asphalt content value to the nearest tenth of a percent. Use this asphalt content value along with two asphalt contents above this amount and two asphalt contents below this amount in the production of mix design samples. Use 0.5 percent above and below the optimum and 1.0 percent above and below the optimum as the four additional asphalt contents. Calculate maximum theoretical specific gravities for each of these five asphalt cement contents.

b. Specimen production.

Using the five mix design asphalt contents, produce three 100-mm-diameter Marshall specimens at each asphalt content. Use approximately 800 grams of combined aggregates following the previously determined aggregate blending formula for each specimen. Just before mixing, the temperature of the aggregates should be 145 ± 5 °C and the asphalt cement should be 135 ± 5 °C. With normal mixing procedures, the temperature of the asphalt mixture during compaction is 120 ± 5 °C. Compact the open-graded asphalt concrete specimens with 25 blows from a 4.5-kg Marshall hand hammer on one side of each specimen. Allow the specimens to air cool for a minimum of 4 hours before carefully removing from molds.

c. Measuring voids total mix (VTM).

(1) Measure the VTM of each open-graded specimen using the following formula:

$$VTM = (1 - WT_{air}/Volume * 1/SG_T) * 100$$

where

Wt_{air} = dry weight of specimen

Volume = B/4 D^2H

D = diameter H = height

SG_T = maximum theoretical specific gravity

(2) Calculate the average VTM for each of the five asphalt cement contents. Select the optimum asphalt content as that

which resulted in a VTM value closest to 30.0 percent. If no VTM averages are in the 30.0 percent range, then slight adjustments to the aggregate gradation may need to be made to achieve the proper void content. Optimum asphalt contents resulting in average VTM values in the 25 to 35 percent range are acceptable, but due to normal production and construction variations, a mix design that provides a 30-percent VTM value is most desirable. (Typical optimum asphalt contents are between 3.5 and 4.5 percent.)

d. Job-mix formula.

(1) The open-graded asphalt concrete job-mix formula will consist of the following information:

(a) Percentage of each aggregate stockpile.

(b) Percentage passing each sieve size for the blended aggregate.

(c) Percentage of bitumen.

(d) Temperature of discharged asphalt mixture.

(e) Voids total mix percentage.

(2) The target temperature of the asphalt mixture when it is discharged from the mixing plant should be 125 $\pm$ 5°C. Select 120°C when ambient temperatures are relatively high and the haul distance from the asphalt plant to the job site is short. Select 125°C when either the haul distance is relatively long or the ambient temperatures are relatively cool. Select 130°C when ambient temperatures are expected to be cool and the haul distance is relatively long. Persistent high winds during construction may also require mix production temperatures to be in the 125°C to 130°C range.

B-2. Resin Modified Portland Cement Grout.

a. Preliminary.

(1) Gather representative samples of portland cement, silica sand, Class F fly ash, and resin additive. Minimum sample sizes are 23 kg each of cement, sand, and fly ash, and 4 L of resin additive. Ensure that all materials meet the quality requirements as detailed in CEGS-02548.

(2) Using the grout material proportions specified in CEGS-02548 and shown below, develop a matrix of initial job-mix formulas for laboratory viscosity testing. The goal of the grout mix design is to produce a material formulation which results in a Marsh Flow Cone viscosity of 8.0 to 10.0 seconds. The initial formulations should ensure that a grout formulation can be produced with a Marsh viscosity no greater than the 10.0 seconds maximum. This is accomplished by testing grout formulations with relatively high w/c ratios and the maximum allowable amount of resin additive. Typical initial grout formulations tested in a mix design evaluation are shown below.

	Batch Percentage by Weight			
Material	CEGS-02548 Limits	Trial 1	Trial 2	Trial 3
Portland Cement	34-40	37.0	36.0	35.0
Silica Sand	16-20	18.0	17.8	17.7
Fly Ash	16-20	18.0	17.9	17.8
Water	22-26	24.0	25.0	26.0
Resin Additive	2.5-3.5	3.0	3.3	3.5

(3) Although the grout's w/c ratio is unspecified, the desirable w/c range is 0.65 to 0.75. Lower w/c values are more desirable to reduce the risk of shrinkage cracking and for higher grout strengths. Higher w/c ratios are sometimes necessary to produce grouts with Marsh Flow viscosities less than the 10.0-second maximum value. Therefore, the focus of the initial grout viscosity tests is to determine the minimum W/C ratio that will produce a grout viscosity less than or equal to 10.0 seconds. It is important to remember that the resin additive serves as a plasticizer which reduces grout viscosity while reducing the amount of water required.

(4) The standard laboratory grout batch size should be in the 4,000- to 5,000-g range. Calculate the material batch weights based on the desired proportions. Multiple grout viscosity tests are facilitated by first blending the dry ingredients (cement, sand, fly ash) for each test sample and then adding the appropriate amount of water and resin additive during the mixing process. These dry- ingredient batches should be kept in air-tight containers to prevent loss of material or contamination before mixing. Two replicate samples per blend are appropriate for grout viscosity testing.

b. Mixing.

(1) The equipment needed to effectively mix the resin modified pavement grout includes a laboratory mixer equipped with a wire whip mixing attachment and approximately 10-L-capacity mixing bowl, a calibrated set of weight scales, and various small containers to weigh and transfer mix water and resin additive.

(2) Place dry ingredients into mixing bowl and adjust the bowl height so that the wire whip is just off of or touching the bottom and sides of the bowl. Begin mixing the dry ingredients at a slow speed and immediately add the appropriate amount of water. Once all of the water is added, speed up the mixer to a point where the grout is being thrown onto the sides of the mixing bowl. Mix the grout at this high speed for 5 minutes, then add the appropriate amount of resin additive. Mix the grout again at a high mixing speed for an additional 3 minutes before testing for Marsh Flow viscosity.

c. Viscosity testing.

(1) The equipment needed to measure grout viscosity includes a Marsh Flow Cone (Figure 1), a 1,000 mL glass or clear plastic graduated cylinder beaker, a 1,500 mL (approximately) empty beaker or bucket, and a stopwatch. Have this equipment set up near the mixing bowl before the end of the 8-minute grout mixing time.

(2) Immediately after mixing the grout, transfer the grout from the mixing bowl to the empty beaker or bucket. Take note of any lumps of material or excess sand in the bottom of the mixing bowl. (Excess lumps indicate inadequate mixing and render the grout useless for viscosity testing.) Immediately fill the Marsh Flow Cone with about 1,100 mL of grout. (A consistent head of grout in the flow cone is achieved for all viscosity tests by marking an 1,100 mL fill line inside the flow cone.) The flow cone outlet is plugged by simply placing one's finger over the outlet opening. Immediately after the flow cone is filled to te 1,100 mL fill line, position the cone over the 1,000 mL graduated beaker. Release the grout opening and start the stopwatch timer simultaneously. Measure the time of flow for 1 L of grout from the flow cone to the nearest tenth of a second.

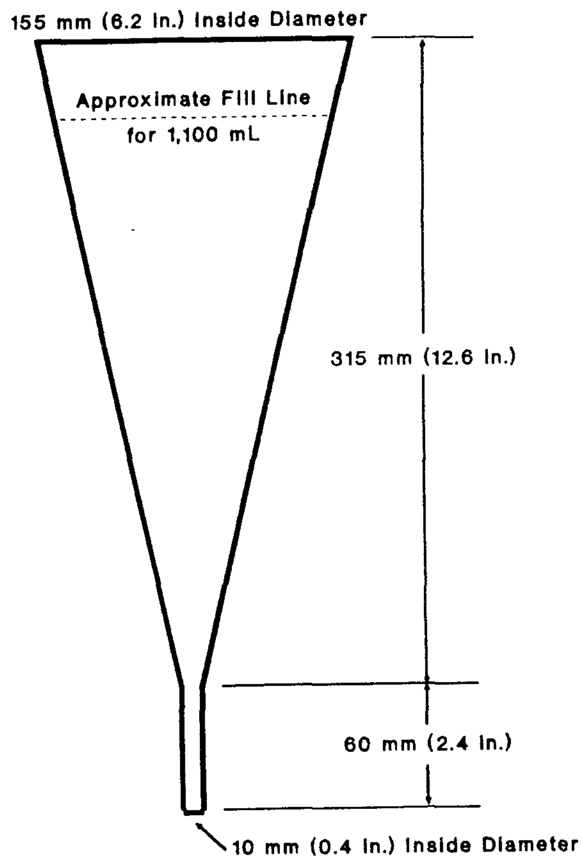

Figure 1. Cross-section of Marsh Flow Cone

(3) Record each test sample's viscosity, averaging the two replicates for each blend. Adjust the grout mix proportions as needed with the following considerations:

(a) Any grout viscosity between 8.0 and 10.0 seconds is acceptable. It should be noted, however, that when field construction temperatures are expected to be comparatively high (greater than 32°C) and/or the open-graded asphalt concrete voids are expected to be considerably low (less than 30 percent), then lower viscosity grouts will help to ensure easy grout application and full grout penetration. In most cases, these variables are unknown; therefore, it is prudent to select the grout formulation which has the lowest viscosity.

(b) It is best to develop a grout job-mix formula with water and resin additive contents below the maximum allowable limits to allow for small additions of these ingredients in the field if necessary to meet viscosity requirements.

(c) Lower w/c ratios are more desirable for a number of reasons: they tend to produce grouts of higher strengths; they reduce the chances for drying shrinkage cracking; they produce grouts which are more consistent and better able to keep the sand in suspension during mixing and placement.

(d) When the sand is noted to settle out of solution during or immediately after mixing, it can be expected that similar problems would occur in the field during construction. This problem can be remedied by reducing the amount of sand and increasing the amount of fly ash (both within the specified tolerances) to produce a slightly creamier grout.

(e) When it becomes impossible to meet the viscosity requirements within the specified limits for material quantities, there usually is a problem with a particular ingredient. Some of these deficiencies are detectable, while others are not. These material deficiencies may include one or more of the following: grout sand which is too coarse, portland cement which is highly reactive during the early stages of the hydration process, fly ash with excess cementitious nature. When it is possible to isolate the problem material in these instances, the only recourse is to substitute another material from another source whose physical or chemical difference will likely solve the problem.

d. Job-mix formula. The grout job-mix formula will consist of the following information:

(1) Percentage (by weight) of each mixture ingredient rounded to the nearest tenth of a percent.

(2) Type and source of portland cement.

(3) Source of fly ash, silica sand, and resin additive.

(4) Marsh Flow Cone viscosity of job-mix-formula grout.